LIGHTING FOR PRODUCTION AND SAFETY

Industrial lighting

LIGHTING *for* PRODUCTION *and* SAFETY

COMPRISING THE STUDY AND
SELECTION OF A SYSTEM OF
ILLUMINATION WITH A VIEW
TO ULTIMATE EFFICIENCY
OF THE PLANT

BY

WILLIAM A. D. EVANS

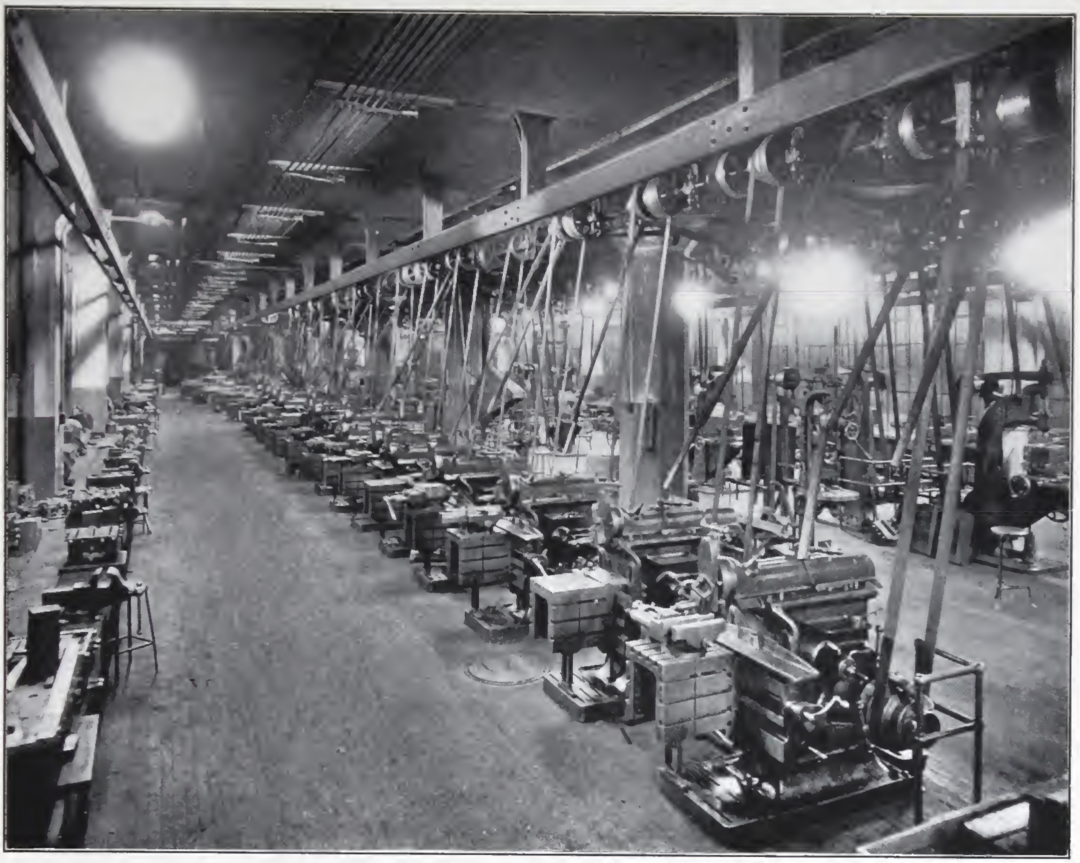
FIRST EDITION

BETTER THAN COOPER HEWITT LIGHT INCREASES PRODUCTION DAYLIGHT

COOPER HEWITT ELECTRIC COMPANY

EIGHTH AND GRAND STREETS, HOBOKEN
NEW JERSEY

NOTE: The half-tone illustrations in the brochure are made from un-retouched photographs, taken under Cooper Hewitt Lamps. This is proven by the fact that the windows in every case appear dark, indicating that no daylight was used.



MACHINE SHOP—DODGE BROS., DETROIT, MICH.

Daylight was formerly considered unapproachable in excellence because of its perfect diffusion, steadiness, and ease on the eyes. All of these qualities are now readily obtainable with Cooper Hewitt light. The illustration is an example of such lighting.

Lighting for Production and Safety

Introduction

IN all manufacturing processes, the main object is to produce goods at the lowest possible cost consistent with the quality desired. The cost of a finished product depends upon the cost of the raw material, the labor, and the indirect fixed charges. With the first item, this article has no direct relation, while the functions of the remaining two will be discussed.

For a manufacturer to increase his profits, one of two things is possible—either (1) decrease his wages and indirect expenses, and produce the same amount of goods, or (2) increase his raw material consumption and produce more goods with no increased cost for wages, and with only a slight increase in indirect cost. Both of these suppositions depend primarily on the wage expense or the labor item. The condition of producing work with labor depends entirely upon the efficiency of the individual. Mr. F. B. Allen has graphically shown the relation of shop conditions to producing efficiency, as shown in Fig. 1.

It will be seen from the chart below that both willingness to work and ability to work depend in a great degree upon the light. If an employee cannot see properly, it undoubtedly depreciates his ability to work, and slows down production; moreover, if his surroundings are dark, and it requires more effort on his part to perceive different operations, his willingness to work is impaired, and consequently production is not kept up to its limit.

Up to about twelve years ago, when a manufacturer or engineer designed a factory and the lighting question was under consideration, one of two systems was available—the open gas burner or the individual incandescent carbon lamp. Today both of these systems are obsolete and have been discarded in most of the older factories and are never recommended for new factories.

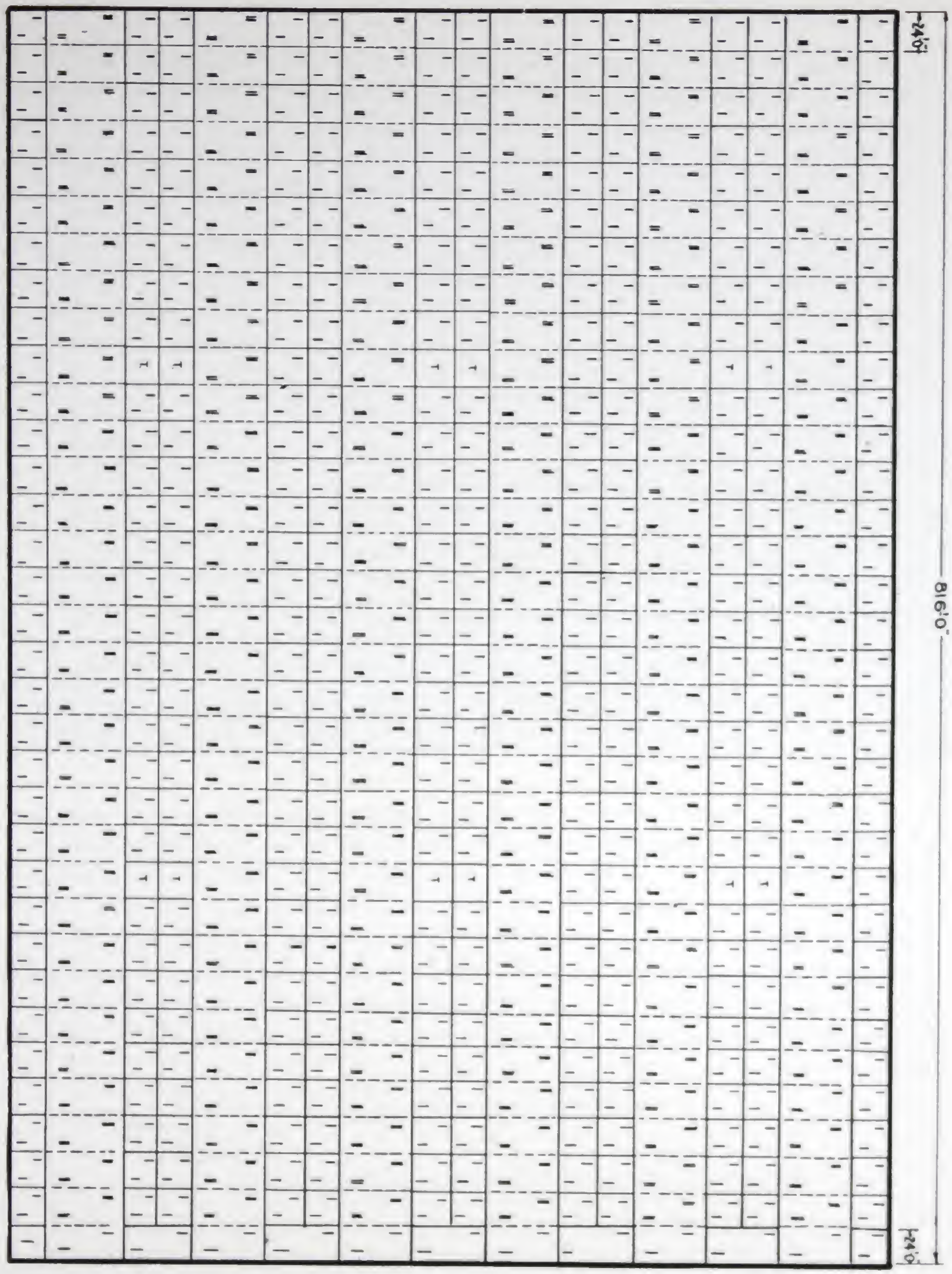
- EFFICIENCY OF INDIVIDUAL DEPENDENT ON
  - ABILITY TO WORK
    - PERCEPTION
      - SIGHT
        - NATURAL LIGHT
        - ARTIFICIAL LIGHT
      - SOUND
      - TOUCH
      - TASTE
      - SMELL
    - INTELLECT AIDED BY
      - EDUCATION
      - SYSTEM
      - EXPERIENCE
    - BODY AIDED BY
      - MACHINERY AND POWER TO OPERATE SAME
  - WILLINGNESS TO WORK
    - CONSCIOUS WILL DEPENDENT ON
      - WAGES
      - MARKET PRICES
    - SUBCONSCIOUS WILL DEPENDENT ON
      - TREATMENT
      - CONDITION TENDING TOWARDS PHYSICAL WELFARE
        - CORRECT LIGHT
        - PROPER TEMPERATURE
        - VENTILATION
        - SANITATION

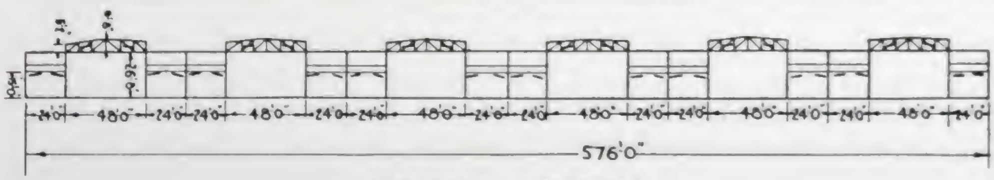
Fig. 1

At the present time gas is practically eliminated from factory lighting for several reasons: the convenience of electric illumination; the presence of an increased fire risk; and greater heat in a surrounding atmosphere which is present in a gas installation. Even with the low cost of gas in some localities, electric light can be produced more economically with the high efficiency units which are now available for factory lighting.

Correct Light

By referring to the efficiency diagram, Figure No. 1, it will be noted that the willingness to work depends upon "Correct light." The question then resolves itself into "What is 'correct light' for manufacturing purposes?" There are certain funda-





SECTIONAL ELEVATION

LIGHTING PLAN, ORDNANCE PLANT—DODGE BROS., DETROIT, MICH.

Twelve acres lighted by 1,600 50-inch Cooper Hewitt Tubes.

SMITH, HINCHMAN AND GRYLLE, *Architects.*

— = Type P Lamp

= = Type PP Lamp

ERNEST WILSHER, *Elec. Eng.*

mental characteristics which all lights should have. Unfortunately, they do not all have them, but it is necessary that a system be adopted which will be as free from faults as possible.

Illumination Intensity

Light, to be correct, should be of such intensity that an operator can work without straining the eyes, and yet not be of such high intrinsic brilliancy that the pupil of the eye contracts to such an extent that it cannot see properly. It should be free from glare and have good diffusion with absence of flicker. It should be of such color that the best vision is obtainable, and should not cast sharp shadows. Last, but not least, the current consumption and maintenance should be as low as is consistent with good practice.

Summing these up in a different way, the following point should be borne in mind: Provide an illumination that will not dazzle the eye of the operator; one with a low intrinsic brilliancy with as little glare as possible; that will be easy on the eye of the operatives and thoroughly diffused, all of which tend to prevent accidents and safeguard the health of those working under it.

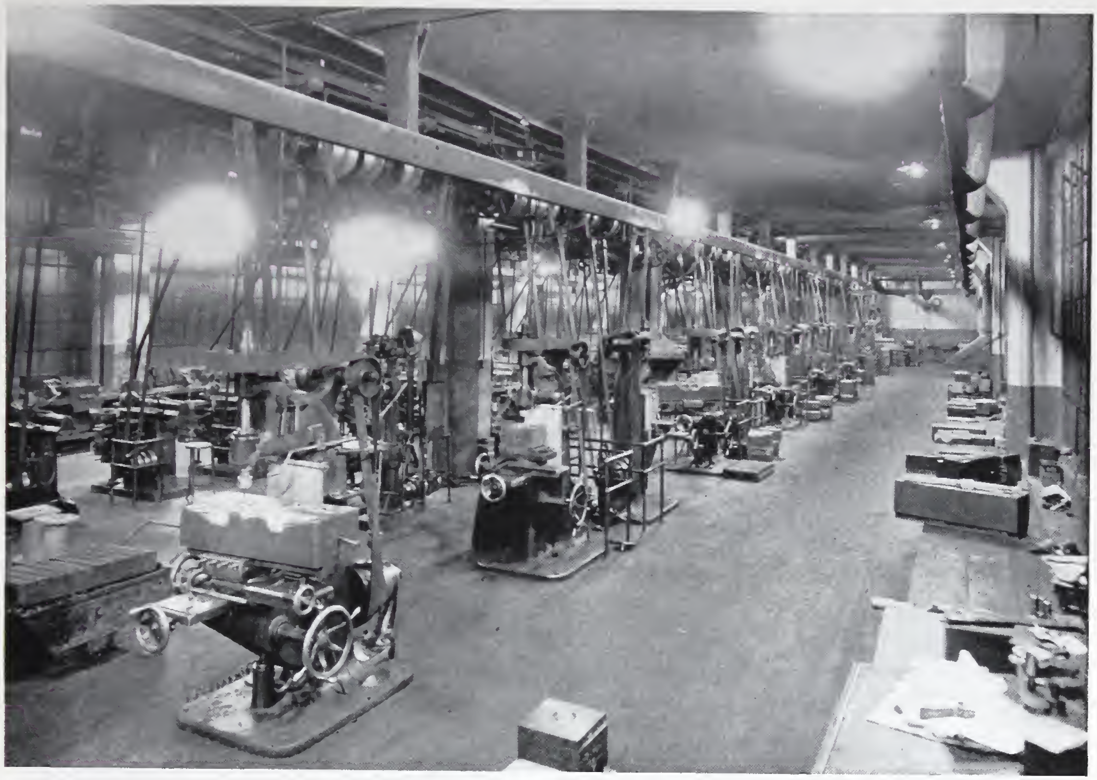
Any system of lighting should be installed with the idea of producing the greatest quantity of goods and of the best quality. In other words, design the lighting, not with the idea of the "proximate" efficiency of the lighting unit, but after considering the "ultimate" efficiency of the plant.

The intensity of illumination required for factory work depends upon a number of different factors. Dependent upon the class of work, the eye can see fairly well from ½ foot candle up to about 15 foot candles. The class of work primarily governs the necessary amount of illumination. In a foundry where the work consists mostly of making moulds and pouring molten metal into the moulds, the light required is not nearly as intense as that where the fine tool making is being carried on. The following table shows average figures for different classes of work, the lower figures being for coarse work, and the higher figures for extremely fine machine work.

TABLE OF INTENSITY

	Ft. Candles
Drafting Rooms	10—15
General Factory Illumination, Supplemented at each machine	2— 3
Forge and Blacksmith shop	2— 5
Foundry	3— 5
Machine Tools (fine work)	7—10
" " (rough work)	5— 7
Buffing and Grinding	5— 7
Bench work (rough)	4— 6
" " (fine)	9—12
Assembly and Erecting	3— 5
Inspecting	9—12

The lighting of a factory where entirely different operations are carried on, cannot always be accomplished by simply adopting a certain number of outlets for



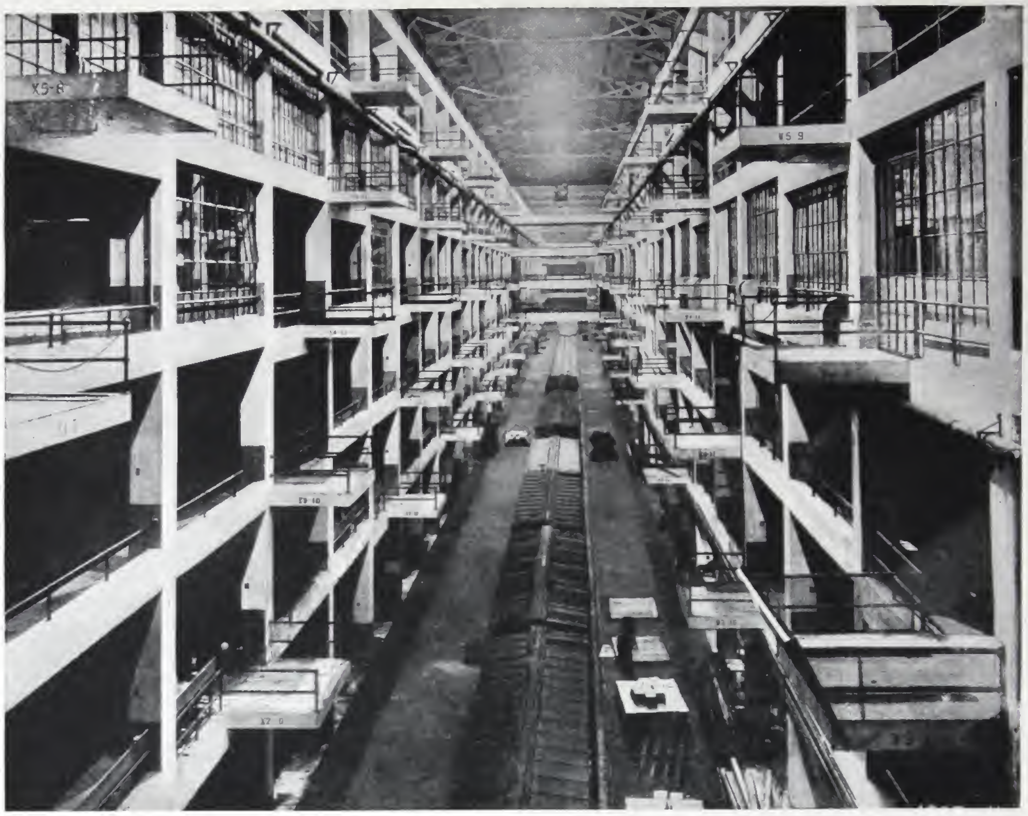
TOOL ROOM—DODGE BROS., DETROIT, MICH.

The modern machine shop is built and equipped with a single purpose in view—securing the maximum output from the machinery and men. Cooper Hewitt light is the only illumination which has proven fully equal to daylight in accomplishing this purpose.

the entire plant and assuming that they will meet all conditions. There will either be too much light for one operation, or too little for another. Before a factory can be properly lighted, a careful study should be made of all conditions which enter into the manufacture of the product, and layouts made accordingly, with the idea of providing the correct amount and kind of light. What will do for one factory will not do for another, and each plant should be considered practically independent of every other one.

Properties of Light Sources

After determining the amount of light necessary, other factors which enter into correct lighting must be considered. Probably the most important of these is glare, and more and more attention is being paid every day to this phase of the lighting question. "Glare is bright or dazzling light," and not only cuts down the ability of the eye to see accurately, but is also apt to produce eye strain, and should, therefore, be avoided as much as possible. Glare is of two kinds: first, that of the light source itself; second, that which comes from the reflection of bright metal parts. Glare depends in a large measure on the intrinsic brilliancy of the light source—that is, the amount of candlepower per square inch given off, which, to a certain extent, depends on the temperature of the illuminant.



CRANEWAY—FORD MOTOR CO., DETROIT, MICH.

The unusual height, as well as the extent of this department of a concern turning out 3,000 automobiles a day, introduced a difficult problem in lighting, which the installation of Cooper Hewitt lamps, as shown, has solved with eminent satisfaction.

The following table given by Ives and Luckiesch shows candlepower per square inch of modern illuminants:

Carbon Arc (Crater)	84,000
Flaming Arc	5,000
Nernst Glower	3,010
Tungsten (1¼ Watt C.P.)	1,600
Carbon Incandescent (2½ Watt C.P.)	400
Welsbach Mantle	31
Cooper Hewitt Tube Lamp	14.9
Kerosene Flame	9

In addition to the above table the intrinsic brilliancy of the *gas-filled tungsten or nitrogen lamp is approximately 2,200.*

By use of certain shades and globes the brilliancy of arc and incandescent lamps can be materially reduced; also by frosting, the brilliancy of the tungsten lamp is brought down to a usable figure. The question of glare is so vital and has been the cause of so much eye strain, that lamps of high intrinsic brilliancy should never be placed in the line of vision without proper protection or shading from the eye.

By diffusion of light is meant the ability of the illuminant to distribute light in all necessary directions, thus tending to produce an even illumination. A lamp in which the light source is a small point will not distribute its light as evenly as one in which

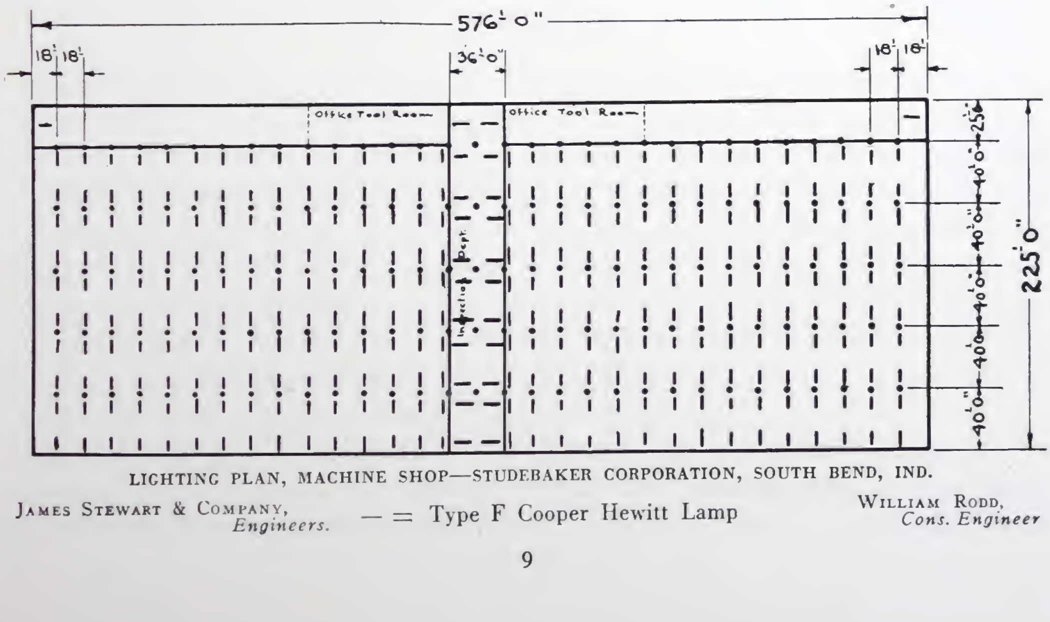
the light emanates from a large source. Good diffusion from a light source is necessary, as it not only insures even illumination, but prevents dark spots and sharp shadows.

The light used should be steady, that is, there should be no flicker. Under most conditions flickering light is as bad as glaring light. Where lamps flicker, due to inherent features, such as in arc lamps, or due to outside conditions, as the varying of the voltage supply or due to operating lamps on low frequency alternating current circuits, the pupil of the eye is continually opening and closing, endeavoring to accommodate itself to different intensities of light, and fatigue results which not only depreciates the "ability to work," but also the "willingness to work."

Daylight

White light, or light from the sun, is considered the ideal color by which all color effects are defined. Further, no artificial illumination in commercial use has a color value which can exactly replace daylight. Some light will make blue look black, and others make red look black, due to the absence of sufficient lines in the spectrum. Therefore, when it comes to the question of obtaining artificial light to replace daylight, the idea of being able to reproduce daylight colors should not enter into consideration, and only features which enter in the selection of light from a color standpoint should be ease on the eyes, and efficiency of light production which ensures an economical installation.

Sunlight or daylight is made up of seven spectral colors, ranging from red rays, which are known as the long wave lengths, down through orange, blue, green, indigo, and violet rays, which are the shortest wave lengths. The rays toward the red end of the spectrum are known as the heat rays, and those toward the violet are known as the chemical or actinic rays, and are the ones that are photographically active. The sun contains all of these rays, as do all light sources which emanate from solid conductors, and if these latter had the rays proportioned in the same manner as the sun, they would emit "white light." Light sources which depend on the conduction of electricity through gases or vapors for the production of light give what is known



LIGHTING PLAN, MACHINE SHOP—STUDEBAKER CORPORATION, SOUTH BEND, IND.

JAMES STEWART & COMPANY, *Engineers.* — = Type F Cooper Hewitt Lamp WILLIAM RODD, *Cons. Engineer*

as a line spectrum, that is, their color is confined to certain lines of the spectrum, and in some cases all of the colors are not represented, as in the Cooper Hewitt Lamp, where there is no red line.

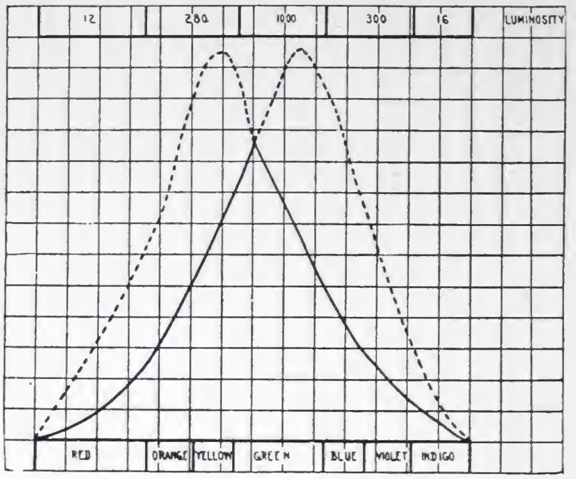


FIG. 2

Each of the different lines of the spectrum has a different visual effect, as shown in Figure No. 2. The relative luminosity of the different colors is as follows:

Red	12
Yellow	280
Green	1000
Violet	16

This means that to see as clearly with a light composed entirely of red rays, as with one of green, we would need eighty-three times as much energy transformed into light. The most efficient light would come only from the mono-chromatic green line, known as Line 546, which for the same energy consumption would give about 100 times as much light as given by an ordinary tungsten lamp. The light of the firefly is confined to approximately this one line.

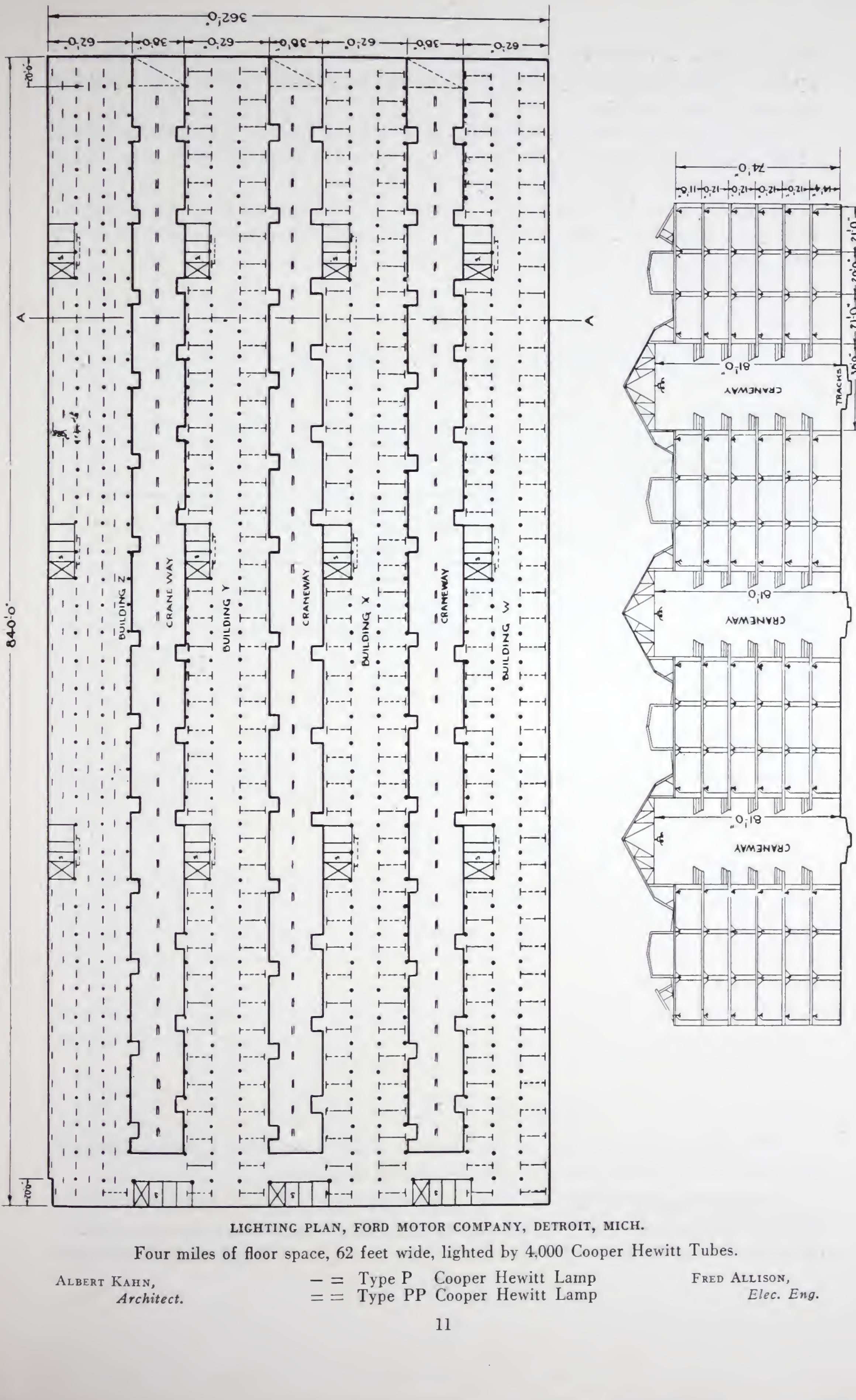
While the green line mentioned above shows the greatest luminous efficiency, another feature has been demonstrated conclusively, which is that a light which is very rich in one color increases vision materially over a light which is composed of different colors. That is, if we had 100 c.p. of one color light, such as a Cooper Hewitt, it would require almost twice as much light from a tungsten lamp to make details stand out as distinctly. This quality is known as "visual acuity," or sharpness of vision. The reason for this is that in a light composed of different colors, the eye endeavoring to see detail has to focus for all the different colors of the spectrum, and they are not all brought together at the same point, and thus the detail is not brought out as sharply as when the light approaching one color or monochromatic light, is used. In the latter case, the eye has to focus only for this one color.

The condition of not focusing properly for all colors is known as chromatic aberration, and while it is impossible to correct the faults of the eye in this respect, lens manipulation takes account of this fact in the making of camera lenses, and they are ground so that the different colors of the object will focus accurately on the plate.

In metal working plants it is necessary to see clearly punch marks, scribe marks, and also to read blue prints correctly, as well as to gauge and measure material accurately with micrometer. A light of one color enables the eye to focus more accurately for this work than light composed of different colors of the spectrum.

Cost of Lighting

The cost of electric lighting is insignificant in comparison with the amount of wages paid out. In most cases an average of $1\frac{1}{2}$ Watts per square foot will give sufficient light for fine work. The cost of the latter amounts to about 1 per cent. of



LIGHTING PLAN, FORD MOTOR COMPANY, DETROIT, MICH.

Four miles of floor space, 62 feet wide, lighted by 4,000 Cooper Hewitt Tubes.

ALBERT KAHN, *Architect.*	— = Type P Cooper Hewitt Lamp = = Type PP Cooper Hewitt Lamp	FRED ALLISON, *Elec. Eng.*

the labor cost. A loss of two to five minutes per day of a worker's time may be made up by an efficient system of proper, adequate lighting, which will more than pay for the cost of the installation.

It has been stated that the entire cost of adequately lighting all of the industries of the United States would be less than the yearly cost of the accidents now occurring in those industries, due to lack of proper illumination.

It would seem, then, that no factory owner should hesitate in giving plenty of light to his employees for the different operations required, when the cost is so slight, and chance of increased production so great.

Safety

Another side of the economical phase of adequate lighting is the safety question. It has been well demonstrated by the figures of the liability insurance companies that the number of accidents vary during the year, the greatest number occurring during the months of November, December and January, or the months of shortest daylight working hours, that is, the time when it is necessary to use artificial light the most (Figure No. 3). Good lighting has been taken up by all the insurance companies, and is aptly considered one of the necessary safety devices. More and more thought is being given to designing lighting installations in all industries, so as to obviate dark places and spots which are liable to be causes of accidents. In this connection, glare is also a most important factor, and due thought should be given to eliminating bright light sources in the field of vision.

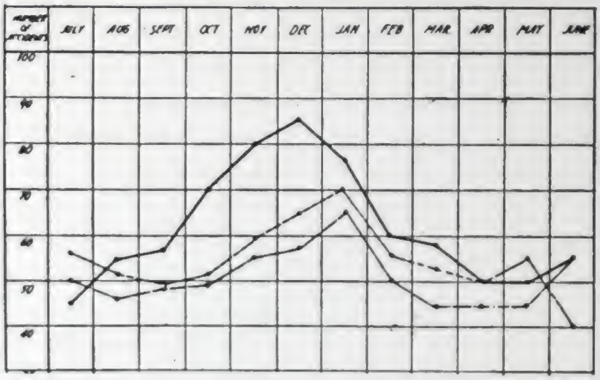


Fig. 3

With the universal adoption of Workmen's Compensation Laws, the question of safety has become extremely important to the manufacturer from an economic standpoint. Anything that will decrease the liability of accident in factories should be welcomed by factory owners, and considering the cheapness of good lighting, this phase of the situation should not be neglected.

In a recent article by Mr. R. E. Simpson, of the Travelers' Insurance Company, he estimates that *25 per cent. of all accidents* occurring in and about industrial plants in the United States is due to inadequate or poor lighting.

Systems of Illumination

After considering the value of good lighting and the necessary qualifications, the next point to be considered is the system and unit to be used.

For factory lighting there are three general systems available, localized lighting, general lighting and a combination of the two. Formerly, all factories were lighted with the localized system—that is, 8 or 16 c.p. incandescent lamps were placed over

each machine. The operators received light on one spot which had a radius of about one foot. Everywhere except directly beneath the lamp, the machine was dark. In most cases the lamps were not protected by reflectors, nor were they frosted. The operators had continually in front of them a glowing filament with an intrinsic brilliancy of about 1,000 c.p. per square inch, and unconsciously each time the head was raised so as to bring the lamp in the field of vision, the pupil of the eye contracted to shut out the excess light from the retina, and when glancing away toward a dark spot the reverse occurred. This continual contracting and opening of the pupil retarded the vision and slowed down the work. Moreover, unless an operator was working directly under the lamp, there was not enough light to see the material properly, and poor work resulted. The old localized system was not only bad for the eye, on account of the glare, but was bad for the production, as no operator could work properly under these conditions, and night production was invariably less than day production.

This has been remedied to a certain extent by the introduction of reflectors and shades, which not only keep the direct light out of the eyes, but also widen the spot illuminated. Even with the reflectors, however, results are not as good as they should be, as there is always a slight portion of the light source visible and unless a large number of lamps are installed, the intensity of illumination will vary materially over different portions of the machines.

Formerly the position of the lamp was continually changed by the operator and as he was usually working on greasy material, the lamp, therefore, in a short space of time was covered with oil, and its candlepower was materially reduced. Without a doubt the majority of lamps used over machines due to this collection of oil and grease are not giving more than approximately 50 or 60 per cent. of their original candlepower.

In a number of cases where individual lighting is used, the operator is apt to take the lamp out of the socket and use it in his home. One large automobile plant estimates that they lost in one year $9,000.00 worth of lamps in this manner.

General Lighting

The second system consists of general lighting, and this is being adopted more and more for efficient factory lighting. In designing a general lighting system, it is necessary to adopt for certain areas of floor space a definite intensity of illumination and then install sufficient fixtures or units to maintain this general average intensity.

By designing a proper general lighting system, the glare can be reduced to a minimum, as lights can almost invariably be placed out of the field of vision, and when the illumination is practically uniform, the eye is not in a constant state of change, and the pupil adapts itself for one degree of intensity and no lessening of speed occurs when an operator changes from one position, at the machine, to another. The main criticism of the general system of illumination is that it may be more expensive to install than the individual system, but this is more than offset by the advantages derived, as mentioned above, and also, that the room lighted in this manner is much brighter and more cheerful, which is conducive to the willingness of the operator, and, moreover, the danger from accidents is greatly diminished, as dark spots are eliminated.

ASSEMBLING FLOOR—DAVIS MANUFACTURING CO., MILWAUKEE, WIS.

Daylight lighting was duplicated in this shop by arranging the lamps along the wall and between the bays, thus having all illumination come from the sides. The tubular shape of the Cooper Hewitt lamp particularly adapts itself to this form of lighting.

In some cases, where a general system of illumination is in use, not enough light is provided on machines where close work is required, and individual lamps are installed to insure sufficient intensity for close work. This system is open to the objection (though not in as great degree as with the straight individual system), that there is present too much glare and that the illumination varies materially over different portions of the machines. However, it gives the room a more cheerful appearance, and tends to prevent accidents. It is, in some cases, less expensive than a complete general illumination method.

It should be borne in mind, however, that a good general system of illumination which is designed to give adequate illumination, and good diffusion with the absence of glare, no matter how expensive it may be, will soon pay for itself by the increase in production.

There can be cited one specific case in a large factory which was formerly lighted by individual incandescent lamps and operated up to what was thought to be its maximum efficiency, but since the installation of an overhead system of Cooper Hewitt Lamps, properly laid out, all individual lamps over the machines have been eliminated and on all work that was possible to be accurately checked, an increase in output of 16 per cent. per man was shown.

The finest detail work, such as reading micrometers and gauges, was found to be much easier than under the old system and *fully as accurate* during the hours when

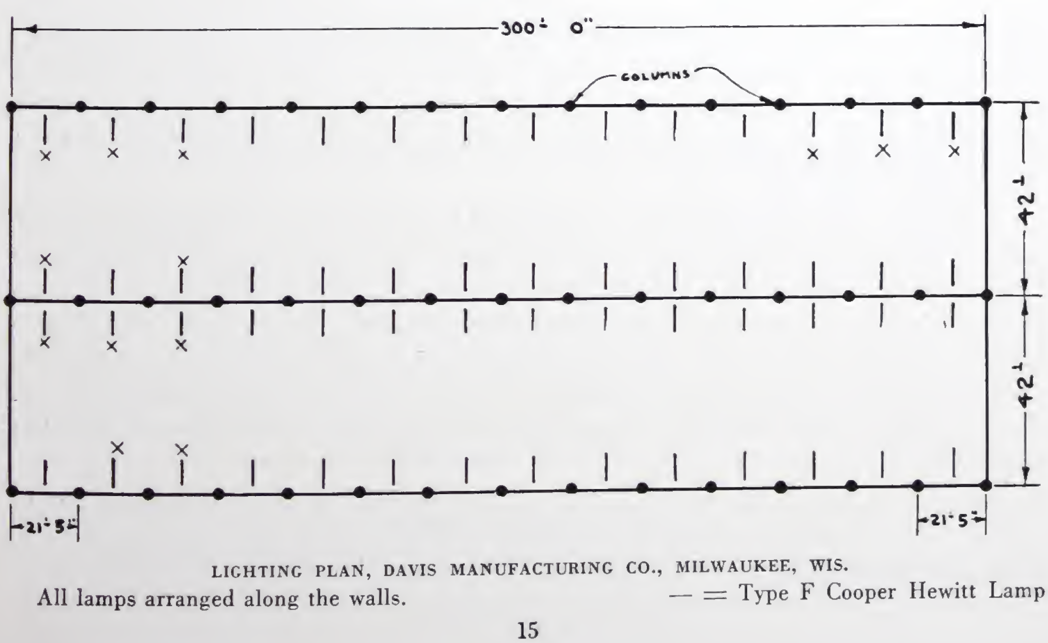
artificial lighting is necessary, as under the best daylight conditions. Operators working during daylight are not confronted at night by a lighting system to which they have to adjust and change all their movements, but by one which replaced daylight as nearly as possible.

Types of Units

There is not any doubt that a general lighting system meets all requirements better than an individual system, and the next point to consider is the type of unit best suited for this system. At the present time, there are practically only two different types of units which are suitable for factory lighting—tungsten lamps or Cooper Hewitt Lamps. While enclosed carbon arc lamps could probably be used for a general lighting system, they are so uneconomical in comparison with either of the above mentioned units, that they do not enter into the question of modern factory lighting, and, therefore, tungsten lamps and Cooper Hewitt Lamps only will be considered.

These two units differ radically in their fundamental physical characteristics and their construction. A brief description of the salient features of each will be given.

The tungsten lamp, as is well known, is an evolution of the old carbon filament lamp, in which the carbon filament is replaced by one made of metal tungsten. This metal, by various processes, is drawn into the form of a wire, and is mounted on a stem which is sealed into a glass container of the proper size, and the air is then exhausted by mechanical and chemical means and the lamp then sealed off. In some cases the bulb is filled with nitrogen, which permits the filament to operate at a slightly higher temperature. When the proper voltage is applied to the lamp, current passes through the filament, it becomes heated to incandescence, giving off a yellowish-white light. These lamps are made in all sizes, ranging from 10 watts up to 1000 watts, and are also manufactured for voltages varying from 100-130, or 200 to 250 volts. Higher wattage lamps require a heavier filament, and higher voltage



LIGHTING PLAN, DAVIS MANUFACTURING CO., MILWAUKEE, WIS.

All lamps arranged along the walls. — = Type F Cooper Hewitt Lamp

ERECTING SHOP—JEFFREY MANUFACTURING CO., COLUMBUS, OHIO

The lighting of large works introduces a special problem in the placing of lamps, which must be above craneways and other obstructions. A general illumination of sufficiently high intensity to avoid the necessity of individual lamps, and so diffused as to eliminate deep shadows, is the ideal result to be obtained. The peculiarities of the Cooper Hewitt lamp enable it to fulfill all of these conditions to a degree equalled only by the best daylight. The illustration shows the remarkable distinctness with which this light brings out details, while giving a diffusion that renders objects plainly visible in the most isolated locations.

lamps require a longer filament, or else one of a smaller diameter than a corresponding lamp of the same wattage for a lower voltage. The 220 volt lamp, therefore, generally has a longer filament of smaller diameter than the 110 volt lamp of the same wattage, and for this reason is apt to be more fragile, and, moreover, does not have as high efficiency.

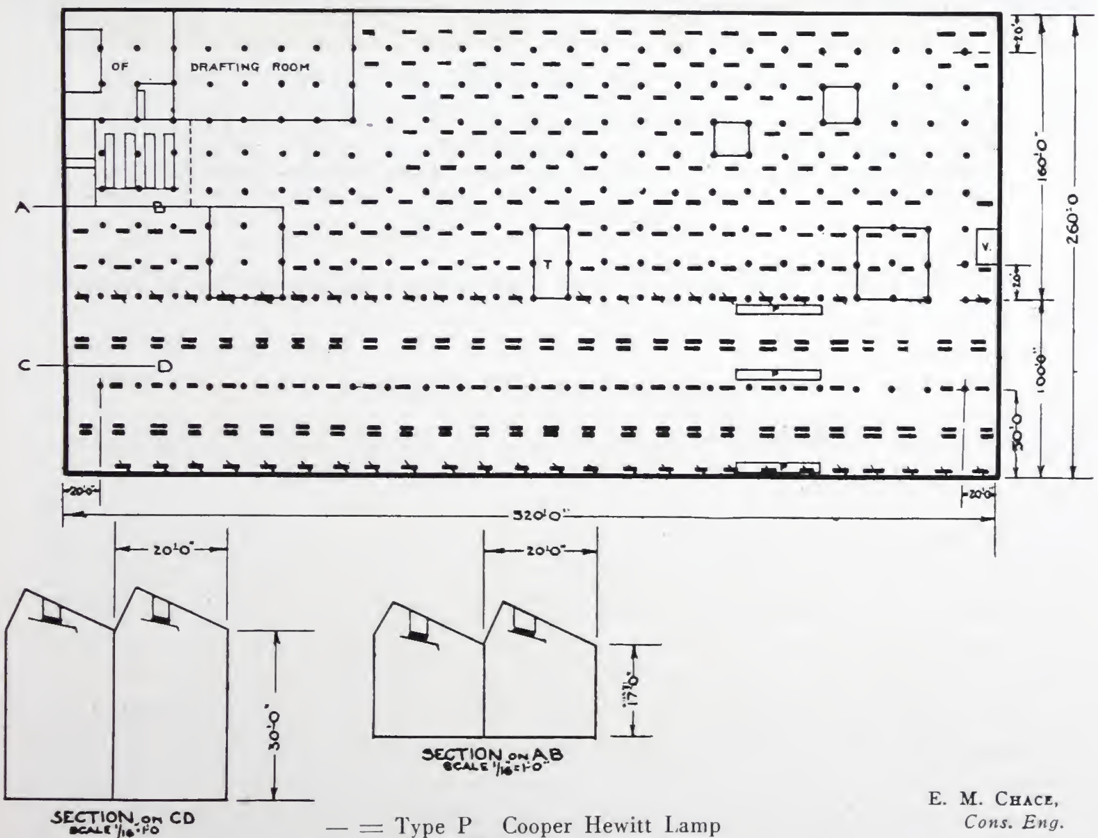
The lamp when burning gives a steady light, and there is no flickering present, except when run on alternating current circuits of low frequency. The intrinsic brightness of the filament is extremely high—between 1000 to 2000 c.p. per square inch—and unless lamps are kept out of the field of vision glare results. Even when lamps are placed high, if the rays strike bright metal spots, the resultant reflection is very noticeable and annoying, and lamps in most cases should be protected by enclosing shades, deep reflectors, or at least frosted, which will reduce this effect materially.

In all cases lamps should be provided with suitable reflectors to direct the light in the proper direction and to provide sufficient intensity on the working plane to give good distribution.

The selection of a proper reflector is just as important as the proper choice of a unit, and a great many plants are equipped with lighting systems not giving the desired results, due to improper selection or design of the reflectors, or units, which do not direct the light properly. To sum up, it may be said that if tungsten lamps are provided with suitable and shaded reflectors, so arranged as to be kept out of the line of vision, they meet the conditions of a good illuminant as regards lack of glare and fairly good diffusion.

On the question of the color, the tungsten lamp gives to a well-lighted room a warm tone. This is due to the preponderance of red and yellow rays in the spectrum, and to the small amount of blue and violet rays present. All lighting from earliest candle flame up through oil lamps, the gas flame, and the carbon lamp has tended toward the yellow or red, and the tungsten lamp falls into this category and seems an illuminant of a natural color. However, it is far from actual daylight color and its small amount of short wave lengths prevent it from being used as a perfect substitute for daylight in the matching of colors. Practically all blues appear black under it, and it is impossible to differentiate these different shades with any degree of accuracy. This is aptly demonstrated by the large amount of experimental work being done to produce an accurate color matching unit.

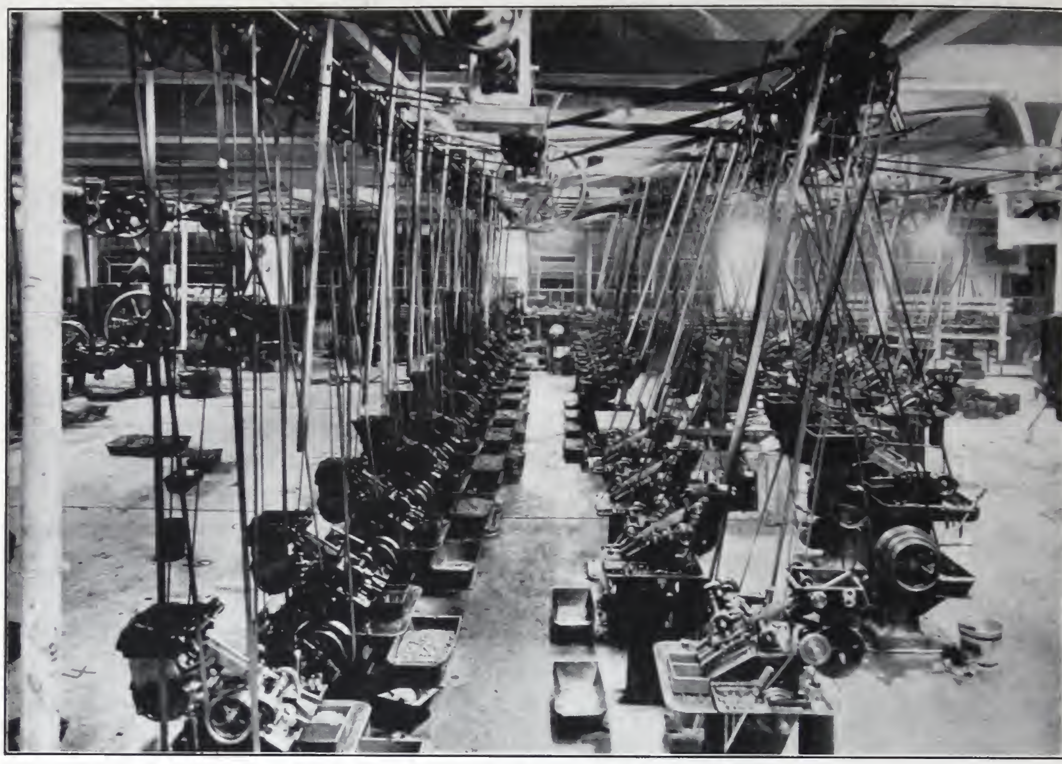
As to the economical aspect of tungsten lighting, it is possible with well-arranged reflectors and proper choice of units, to light a shop with an average of about 100-125



E. M. Chace,
Cons. Eng.

— = Type P Cooper Hewitt Lamp
= = Type PP Cooper Hewitt Lamp

LIGHTING PLAN, GOULD AND EBERHARDT, IRVINGTON, N. J.
Makers of High Grade Machinery.



MACHINE SHOP—PHOELL MANUFACTURING CO., CHICAGO, ILL.

This illustration is typical of a difficult class of lighting problems which still have to be met, namely, buildings of the older form, with inadequate windows and crowded with machinery, shafting, belts, and other obstructions. In the case shown here Cooper Hewitt lamps were installed with due regard to location, and a general illumination produced which proved to be the full equivalent of daylight. In actual fact, the night production exceeds the day output—a result of frequent occurrence with Cooper Hewitt illumination.

watts per employee. Packing and shipping departments require a great deal less than this, while fine machine work will require considerable more.

Cooper Hewitt Lamps

The Cooper Hewitt Lamp differs radically from all other commercial illuminants, inasmuch as it employs for the conducting medium a gas in place of a solid. The lamps are made of lead glass tubes, either 20, 35, or 50 inches in length, in which the mercury is placed, and after the air in the tube is exhausted, sealed off and the current is introduced into the tube by means of platinum wire sealed into the glass at each end. By passing the current through the mercury vapor in the tube, the former emits light by becoming luminescent. This results in light of a few rays only, having a bluish-green color and not a continuous spectrum as in the tungsten lamp.

The light from the Cooper Hewitt Lamp, coming from a long tube and being distributed equally throughout its length, is of extremely low brilliancy, about 15 c.p. per square inch, and is therefore practically free from glare itself, prevents bright images on shiny surfaces, and thus does away with the glare that usually results from these substances. Even if a tube of this character which gives off 850 candlepower is looked at closely, the pupil of the eye is able to take care of all the light received and does not

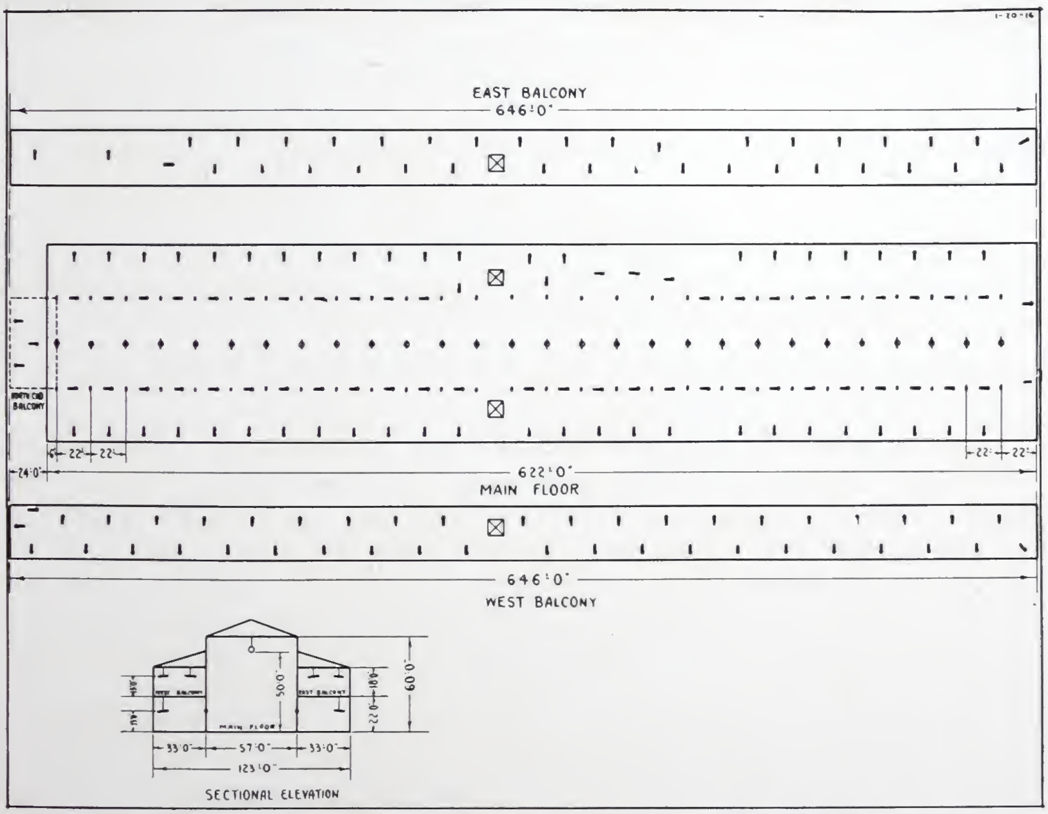
tend to contract as with light sources of high intrinsic brilliancy. These lamps are invariably equipped with reflectors to direct the light in the proper direction, and there is no necessity of frosting them as with the tungsten lamps.

The feature of diffusion with a Cooper Hewitt Lamp is an inherent quality, as the light, being emitted from a long tube, is distributed equally over larger areas, and, moreover, as has often been said, "It shines around corners." The tube being long, the light will shine by obstructions which would be apt to interfere with the light from a small source. Moreover, this feature prevents to a great extent dark, heavy shadows being formed, and these lamps can be laid out in a factory so as to give a room at night the appearance of being lighted by perfectly diffused daylight, that is, no glare, absence of sharp shadows, and good diffusion.

The most striking feature of the Cooper Hewitt Lamp is due to the fact that the spectrum is a line spectrum and not a continuous one. The light in the lamp is concentrated in six lines, two in the violet, one in the blue, two in the green and one in the orange. There is no red present, and it is due to this that all objects illuminated by it, which are of a reddish tone, darken considerably and in many cases become black.

Visual Acuity

About 60 per cent. of the light emitted from the lamp is given off by the green and yellowish-green lines. The most powerful of these is situated at 546, which is



LIGHTING PLAN, ERECTING SHOP—JEFFREY MANUFACTURING COMPANY, COLUMBUS, OHIO
One of several buildings Daylighted by Cooper Hewitts.
— = Type P Cooper Hewitt Lamp
= = Type PP Cooper Hewitt Lamp

the line of maximum visible sensibility, while a second is at 579, which is extremely close to this line. The preponderance of these rays account to a great extent for the high efficiency of the Cooper Hewitt Lamp. On the other hand, as the light is confined mostly to these green bands, the light is of a greenish hue, or is practically monochromatic, that is, a light of one color. Due to this quality, an extremely important feature of the lamp results, which is known as "visual acuity." By visual acuity is meant sharpness of vision, and it results from the fact that under an ordinary lamp containing all colors of the spectrum, the eye attempts to focus for all the colors, and as they are all of different wave lengths, those of the shorter wave lengths are brought to focus by the eye at a different point than those of the longest wave length. While the difference is extremely small, however, it causes a slight blurring of the image and the vision is not sharp. By using monochromatic light, or one nearly monochromatic, the eye simply focuses for this one color with great distinctiveness, insuring extreme sharpness of vision.

The Cooper Hewitt Lamp with this quality has the appearance of practically magnifying extremely small objects, from 1½ to 2 times. This is particularly valuable in machine shops where it is necessary to distinguish fine lines, and it is due to this special quality that the lamp has been used so exclusively in metal working plants.

Another decided advantage of this "acuity value" is in the inspection of materials, as every imperfect piece caught in the early stages of manufacture will save labor, and other expenses.

As was shown in the first part of this paper, the eye is able to see better with a small amount of green light than with any other one color, therefore when shadows are cast by Cooper Hewitt Lamps, they are less dense than by lights of another color, and perception is easier even under these conditions.

From an economical standpoint, the Cooper Hewitt Lamp is the cheapest illuminant for factory use. On account of its high efficiency the current cost is extremely low, and due to the long life of the tubes, the maintenance charge is a very reasonable item. The first cost is higher than with most other units, but as this is a capital charge, the same as the purchase of a machine, the interest and depreciation charges should only be considered.

With the Cooper Hewitt system of illumination, the problem of producing a flat production curve can be realized throughout the entire working period, material produced under this system being in quantity and quality equal to that produced under maximum daylight.

It might be said that it is a factory efficiency system of illumination that maintains the best results in a factory and increases production during artificial working hours, or in the words of users, the Cooper Hewitt light is "BETTER THAN DAYLIGHT."